Effects of sylvicultural activity on ecological processes in floodplain forests of the southern United States

B. Graeme Lockaby and John A. Stanturf

Introduction

In terms of area, riverine systems represent the largest category of forested wetlands in the United States although estimates of their extent in the Southeast vary widely (i.e. 6 to 13 million ha—Sharitz and Mitsch, 1993). In addition to areal significance, riverine forests are very important functionally because of a high degree of hydrologic interconnectivity within the landscape and, consequently, have great potential for influencing the chemistry and biology of aquatic systems (Brinson, 1993). As a result, management activities that alter the biogeochemical transformation function of riparian forests have the capacity to influence much larger portions of the landscape.

Floodplain forests are typically occupied by a mosaic of vegetation communities that are defined by hydroperiod (Shelford, 1954; Hodges, 1995). Areas such as deepwater swamps with long hydroperiods may be dominated by water tupelo (*Nyssa aquatica*) and baldcypress (*Taxodium distichum*) while the wetter portions of true floodplains could be occupied by sweetbay (*Magnolia virginiana*), overcup oak (*Quercus lyrata*), red maple (*Acer rubrum*), water hickory (*Carya aquatica*), and laurel oak (*Quercus hemisphaerica*). Moderately well-drained areas may support sweetgum and water oak while cherrybark oak (*Quercus falcata var. pagodaefolia*) and black gum (*Nyssa sylvatica*) often occur on better drained sites (Sharitz and Mitsch, 1993). While floodplain forests are clearly dominated by deciduous species, the occurrence of slash, spruce, and/or loblolly pine (i.e. *Pinus elliottii*, *glabra*, and *taeda* respectively depending on the associated hydroperiod) is also common.

Annual litterfall and total aboveground biomass production range between 3 to 7 and 7 to 20 t/ha respectively among types of riverine forests in the southeastern US (Brinson 1990, Conner 1994). The high values of both ranges indicate that some floodplain forests are among the most productive forests of the temperate zone (Bray and Gorham, 1964; Rodin and Bazilevich, 1967). Brinson notes that no latitudinal patterns emerge from a review of floodplain NPP literature and that this is likely due to the dominance of intrasystem hydrology over climatic variation as the controlling factor behind floodplain NPP.

In general, forested floodplains of the southeastern United States fall into two categories from a biogeochemical standpoint: alluvial (i.e. redwater) and blackwater

(Wharton, 1978; Walbridge and Lockaby, 1994). Alluvial riverine systems are those with watersheds which lie in physiographic units with clayey soils and typically have relatively high concentrations of inorganic ions. Watersheds of blackwater systems lie within the coastal plains (i.e. sandy soils) and streams therein are usually low in inorganic nutrients. Consequently, alluvial systems tend to be eutrophic while those of blackwater systems may be more oligotrophic. The latter statement may be particularly true in the case of P (Lockaby et al., 1994).

Effects of past land-use on present floodplain systems

The current condition of almost all floodplain forests in the southeastern United States reflects the integration of natural factors plus the influence of past human activities (Wharton, 1978). The nature and intensity of previous activities vary widely and were partially dependent on historical patterns in terms of the most prevalent land use activities practiced in a given area. As an example, the spatial pattern of species occurrence in some floodplain forests reflects altered hydroperiods that result from 19th and early 20th century agricultural ditching and/or diking (Lockaby et al., 1995; Stanturf et al., 1995).

Floodplains that were less accessible and/or inherently wetter may not have been farmed but were likely subjected to logging. In most cases, high-grade logging was practiced and only removed valuable species such as baldcypress, oak spp., or pine spp. Logs were removed by a variety of means which included animals, rail-spurs, and, within the wettest areas, pull-boats (Walker, 1991). Influences of selective logging on present-day structure and composition of floodplain forests were more subtle than those associated with agriculture and, consequently, it is difficult to assess the degree to which lasting effects may have occurred. However, with the exception of pull-boat logging and its associated canal systems, the selective logging would cause little alteration in hydroperiod and, consequently, we theorize that most changes in site quality would have been short-term although species composition may have been altered by removal of seed sources.

Sylvicultural systems presently used

Historical use of selection/high grade logging in floodplain forests has evolved to an almost complete reliance at the present time on clearcut systems coupled with natural regeneration (Walbridge and Lockaby, 1994). However, interest in partial cutting is increasing (Meadows and Stanturf, 1995). Clearcut systems may utilize either manual and mechanized methods for felling, the latter obviously necessitating an additional entry by large equipment. The vast majority of log removal systems are ground-based, skidder operations with tire widths sometimes being widened in an effort to reduce ground-pressure (Aust et al., 1992; Stokes and Schilling, 1995). A small percentage of log removal systems are aerial with helicopters serving as the primary transport mode. The natural regeneration methods normally used require no site preparation so that site disturbance is confined to the harvest and log removal phases only.

Responses to sylvicultural disturbance

Hydrology

Harvest operations alone may cause only subtle changes in floodplain forest hydrology and those changes seem to be short-term. The most commonplace hydrologic change is elevation of soil water tables (Aust and Lea, 1992; Perison et al., 1992; Lockaby et al., 1995), an effect that is also common on many upland sites following harvests. The rise is due to a reduction in evapotranspiration which occurs as a result of temporary removal of the transpiring surface. Evaporative losses alone (in most cases) from clearcut areas should not greatly exceed those from closed canopies since soil temperature elevations are usually minimal (e.g. 2–3° C higher within cut areas—Aust et al., 1992; Messina et al., 1995). An exception in terms of the magnitude of soil temperature increase was described by Lockaby et al. (1994) following exposure of dark histosols in south Alabama where increases ranged between 10–15° C. The extent of the change in water table depth is most pronounced prior to re-establishment of a vegetative canopy and, in terms of magnitude, may be small (e.g. 14 cm rise on clearcut plots—Lockaby et al., 1995).

An unusual water table response was documented following harvest of a floodplain forest which developed on dark-colored, organic soils (Lockaby et al., 1994). In this instance, water tables receded (i.e. depth to water tables increased) until vegetation canopies were re-established in the second year after harvest. The authors postulated that this effect was caused by strong stimulation of evaporation from the dark soils, a theory supported by the previously mentioned, very high increases in soil temperature within harvest areas.

Compared to the effects of tree removal alone, floodplain forest hydrology may be affected to a greater extent by design of logging roads, a necessary component of ground-based harvests. Culverts, ditches, and roads designed as elevated berms may alter sheetflow velocity (Rummer et al., 1995) and direction (Lockaby et al., 1995). A possibility exists, if sheetflow is altered to a significant degree, that floodplain functions such as vegetation productivity (Young et al., 1995) and nutrient transformation (Lockaby et al., 1995) could be altered as well.

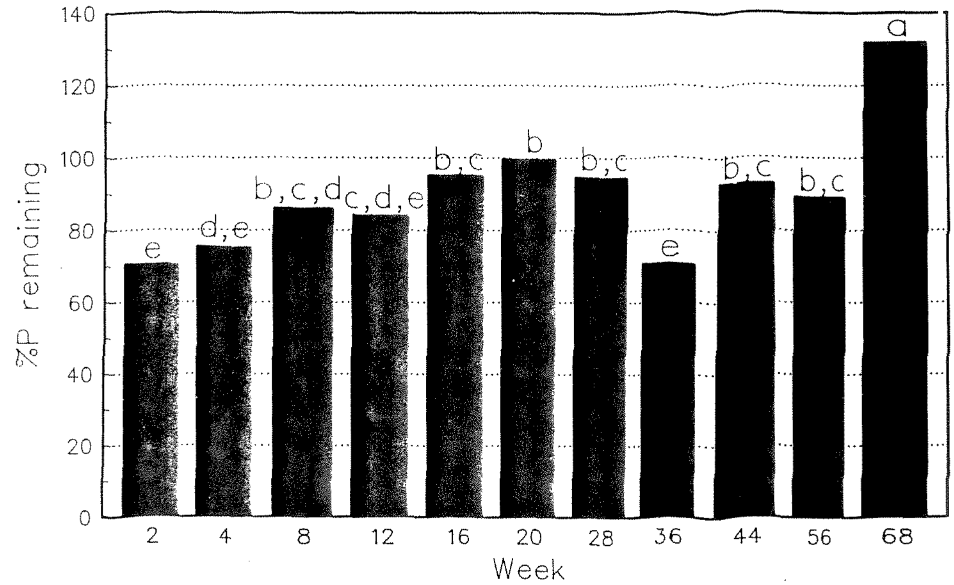

Figure 1a:
Percent of original P content remaining in litterbags placed in control plots on Little Escambia Creek floodplain in south Alabama.

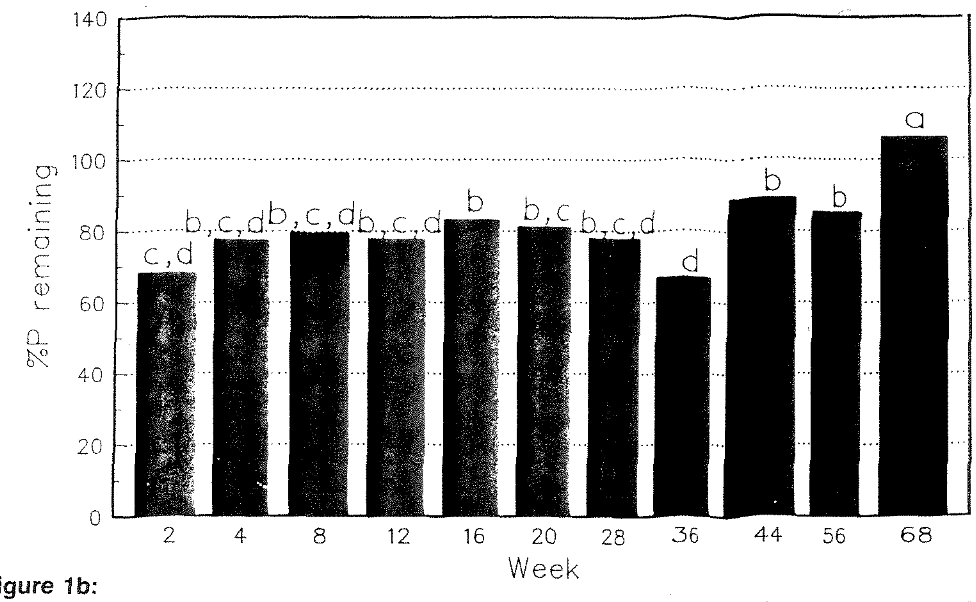

Figure 1b:
Percent of original P content remaining in litterbags placed in helicopter harvested plots on Little Escambia Creek floodplain in south Alabama.

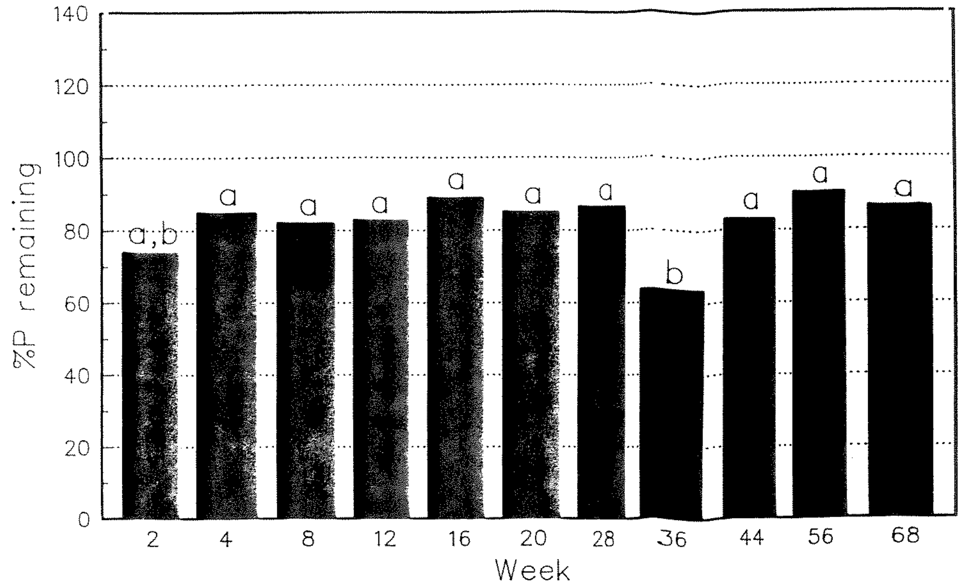

Figure 1c:
Percent of original P content remaining in litterbags placed in skidder harvested plots on Little Escambia Creek floodplain in south Alabama.

Biogeochemistry

Several studies have examined the effect of harvest disturbances on rates and magnitude of nutrient cycling within floodplain forests as well as on geochemical input-output relationships. Although harvest studies in upland forests have sometimes demonstrated a reduction in decomposition rates (Will et al., 1983), similar investigations in wetlands have generally shown accelerations (Mader et al., 1988) or no change (Lockaby et al., 1995). The divergent responses between upland vs. floodplain systems probably reflect the greater tendency in the former for soil moisture to become limiting to microbes following canopy removal and subsequent elevation of soil temperatures.

Temporal patterns of N and P immobilization/mineralization in decomposing litter appear to be particularly sensitive to changes in soil microclimate brought about by harvest disturbance. In Fig. 1a-c (Griffin et al., 1993), P patterns become less dynamic (i.e. dampened oscillation) as the severity of harvest disturbance increases in the order control, helicopter, skidder. The utility of comparing treatment conditions within a floodplain on the basis of these patterns is derived from the integration of microbial activity and nutrient availability which is reflected therein. Temporal pattern alteration will affect the timing and magnitude of nutrient availability in some floodplain systems and, thus, may exert an influence on (1) species composition of replacement vegetation and (2) geochemical source/sink relationships.

The capacity of floodplains to serve as sinks, sources, or transformation zones for nutrients (depending on position in the landscape, magnitude of elemental inputs, and time since disturbance) has been clearly documented (Brinson, 1993). In recent history, there has been much concern regarding the degree to which sylvicultural activity might stimulate source behavior for a number of non-point source pollutants (i.e. sediment, nitrate, etc.). However, the magnitude of source activity has been generally shown to be small and the longevity of any effects to be short-term (Shepard, 1994; Lockaby et al., 1994; Messina et al., 1995). There are strong indications that, once revegetation has occurred, sediment deposition is stimulated by enhancement of the roughness coefficient and the associated loss of energy in sheetflow (Scott et al., 1990; Perison et al., 1992; Zaebst et al., 1994).

The degree to which sylvicultural disturbance might alter the capacity of a floodplain forest to transform nutrients (Elder, 1985) is less certain than that associated with the aforementioned ono-point source activity. The transformation process is more subtle chemically and biologically than the occurrence of non-point source pollution and, consequently, requires a different study design. Sediment and chemical exchange between sheetflow and floodplain surface soils were studied in the first year following harvests in Georgia (Lockaby et al., 1995). Those authors found few differences between partial harvests and unharvested areas in terms of changes in sheetflow chemistry. Both areas acted to detain basic cations and to release nitrate. The data suggested that total organic carbon (TOC) export was increased from partially harvested areas, probably as a result of the large amounts of coarse woody debris there.

Vegetation composition and productivity

Clear assessments of the degree to which sylvicultural operations may affect the composition and productivity of woody species are hampered by the brief timespans (i.e. 1–2 years) of most studies reported (Lloyd, 1995; Messina et al., 1995). An exception is the harvest response data of Zaebst et al. (1994) which compare woody vegetation characteristics following aerial vs. ground-based log removal in the Mobile River Delta of south Alabama. Although species composition differed between the two log removal systems, total aboveground biomass and stem densities were similar at age 7. Given recent reports of long-term productivity declines following ground-based harvests on upland sites in the southern United States (Haywood and Tiarks, 1994), future productivity assessments of aerial vs. ground-based systems on plots associated with several recent studies (Perison et al., 1992; Lockaby et al., 1994; Lockaby et al., 1995; Messina et al., 1995; Zaebst et al., 1994) are clearly warranted as those stands mature.

It is evident that the mode of log removal used (i.e. whether aerial or ground-based) can make a major difference in terms of species composition in the first year following harvests (Walbridge and Lockaby, 1994). In general, species which reproduce primarily from seed are favored by ground-based operations while those that regenerate via sprouting are favored by aerial harvesting. The divergent responses are probably due to a greater tendency for damage to occur to roots and stumps with ground-based equipment. Whether young stands resulting from the two systems of log removal continue to reflect different species composition as they mature is uncertain.

There also appears to be potential for manipulation of *Quercus sp.* composition in floodplain forests through the use of partial cuts which may preceed a clearcut by a variable number of years (Barry and Nix, 1992). Although there is strong evidence that the type of log-removal system and the occurence of intermediate operations both influence species composition, there remains much uncertainty in mixed-species, uneven-age floodplain forests concerning the best methods to use for guiding composition to a desired outcome (Meadows and Stanturf, 1995).

Amphibian populations

The most commonly used index of faunal habitat quality (as well as general ecosystem integrity (Vitt et al., 1990) in connection with floodplain forest disturbance is amphibian population surveys. This is because amphibians are particularly sensitive to subtle changes in habitat (Pechmann et al., 1989; Blaustein and Wake, 1990; Hayes and Jennings, 1990) and have small ranges (Corn and Bury, 1989). In addition, many amphibian species occupy terrestrial-aquatic ecotones (Wyman, 1990) and, thus, they are particularly suited to evaluations of floodplain disturbance.

In south Alabama, Clawson et al. (1995) found that, immediately after helicopter harvests in floodplain forests situated on organic soils, density was affected only to a minor degree but that diversity declined sharply. However, diversity recovered by six months after harvests presumably as vegetative cover was reestablished and surface soil temperatures began to return to normal ranges. Although the number of species had recovered, shifts in species composition persisted for the two year study duration. Phelps and Lancia (1992), working in the coastal plain of South Carolina, felt that their data suggested greater diversity in clearcut areas even though no statistical differences were found between clearcuts vs. controls. As in the case of vegetative responses, the time required for re-establishment of pre-harvest amphibian populations (or the degree to which re-establishment may occur at all) are unknown.

Conclusions

Existing studies indicate that sylvicultural operations consisting of clearcuts in combination with natural regeneration are compatible in a general sense with the major functions associated with floodplain forests. These operations are particularly compatible with functions if aerial log removal systems are utilized. Based on general observations of perceived impacts on floodplain forests from both historical and current land management scenarios, we believe that those scenarios with less potential to induce longterm changes are those which alter hydroperiod to the least extent.

There remains a need to clarify potential influences of logging roads on hydroperiod and, subsequently, on vegetation productivity and biogeochemical transformation functions. Also, the ecological processes involved with and the effect of land management on the latter function have been little researched. Finally, reassessment of vegetation productivity and faunal population dynamics on floodplains which were harvested 10–20 years ago are badly needed in order to document the degree to which the aggradation of those factors may or may not converge to preharvest states.

References

Aust, W. M. and Lea, R. 1992. Comparative effects of aerial and ground based logging on soil properties in a tupelo-cypress wetland. Forest Ecology and Management 50: 57–73.

Aust, W. M., Reisinger, T.W., Stokes, B.J. and Burger, J.A. 1992. Tire performance as a function of width and number of passes on soil bulk density and porosity in a minor stream bottom. In: J.C. Brissette (ed). Proc. of Seventh Biennial Southern Sylviculture Conference. USDA Forest Service Gen. Tech. Rep. SO-93. Southern Forest Experiment Station, Asheville, NC.

Barry, J.E. and Nix, L.E. 1992. Impact of harvesting activities on oak seedling establishment in a bottomland hardwood forest. In: J.C. Brisstte (ed). Proc. of Seventh Biennial Southern Sylvicultural Research Conference. USDA Forest Service Gen. Tech. Rep. SO-93. Southern Forest Experiment Station. Asheville, NC.

Blaustein, A.R. and Wake, D.B. 1995. Declining amphibian populations: a global phenomenon? Trends in Ecology and Evolution 5: 203-204.

Bray, J.R. and Gorham, E. 1964. Litter production in forests of the world. In: J.B. Cragg (ed). Advances in Ecological Research 2. Academic Press, Inc. New York.

Brinson, M.M. 1990. Riverine forests. In: Ecosystems of the World 15: Forested Wetlands. Elsevier. New York. 527 pp.

Brinson, M.M. 1993. Changes in the functioning of wetlands along an environmental gradient. Wetlands. 13: 65–74.

Clawson, R.G., Lockaby, B.G. and Jones, R.H. 1995. Amphibian responses to helicopter harvesting in forested floodplains of low order, blackwater streams. Forest Ecology and Management. In press.

Conner, W.H. 1994. Effect of forest management practices on southern forested wetland productivity. Wetlands 14(1): 17–40.

Corn, P.S. and Bury, R.B. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management 29: 39–57.

Elder, J.F. 1985. Nitrogen and phosphorus speciation and flux in a large river system. Water Resources Research 21: 724–732.

Griffin, A., Lockaby, B.G. and Jones, R.H. 1993. Influence of harvesting on decomposition and nutrient dynamics in forested wetlands. In: Agronomy Abstracts, p. 349, 1993 Annual Meetings. American Society of Agronomy, Madison, WI.

Hayes, M.P. and Jennings, M.R. 1990. Vanishing amphibians . . new mystery in an old pattern. Mainstream 21(3): 20–23.

Haywood, J.D. and Tiarks, A.E. 1994. Growth reductions in short-rotation loblolly and slash pines in central Louisiana—10th year results. In: B. Edwards (ed). Eighth Biennial Southern Sylviculture Conference. USDA Forest Service. Southern Forest Experiment Station. Asheville, NC. In press.

Hodges, J.D. 1995. Development and ecology of bottomland hardwood sites. Forest Ecology and Management. In press.

Lloyd, S. 1995. Woody regeneration following helicopter and skidder harvest of narrow, branch-bottom wetlands in south Alabama. M.S. Thesis. Auburn University.

Lockaby, B.G., Thornton, F.C., Jones, R.H. and Clawson, R.G. 1994. Ecological responses of an oligotrophic floodplain forest to harvesting. Journal of Environmental Quality 23: 901–906.

Lockaby, G., Clawson, R., Flynn, K., Rummer, R., Meadows, S., Stokes, B. and Stanturf, J. 1995. Influence of harvesting on biogeochemical exchange in sheetflow and soil processes in an eutrophic floodplain forest. Forest Ecology and Management. In press.

Mader, S.F., Aust, W.M. and Lea, R. 1988. Changes in net primary productivity and cellulose decomposition rates in a water tupelo—baldcypress swamp following timber harvest. In: J.H. Miller (ed). Proc. of Fifth Biennial Southern Sylvicultural Research Conference. USDA Forest Service Gen. Tech. Rep. SO-74. Southern Forest Experiment Station. Asheville, NC.

Meadows, J.S. and Stanturf, J.A. 1995. Sylvicultural systems for southern bottomland hardwood forests. Forest Ecology and Management. In press.

Messina, M.G., Schoenholtz, S.H., Lowe, M.W., Wang, F., Gunter, D.K. and Londo, A.J. 1995. Initial responses of woody vegetation, water quality, and soils to harvesting intensity in a Texas bottomland ecosystem. Forest Ecology and Management. In press.

Pechmann, J.H.K., Scott, D.E., Gibbons, J.W. and Semlitsch, R.D. 1989. Influence of wetland hydroperiod on diversity and abundance of etamorphosing juvenile amphibians. Wetlands Ecology and Management 1: 3–11.

Perison, D.M., Lea, R. and Kellison, R. 1992. The response of soil physical and chemical properties and water quality to timber harvest and soil disturbance: preliminary results. In: J.C. Brissette (ed). Proc. of Seventh Biennial Southern Sylvicultural Research Conference. USDA Forest Service Gen. Tech. Rep. SO-93, Southern Forest Experiment Station. Asheville, NC.

Phelps, J.P. and Lancia, R. 1992. Effect of timber harvest on the herptofauna community of a bottomland hardwood forest. In: J.C. Brissette (ed). Proc. of Seventh Biennial Southern Sylviculture Conference. USDA Forest Service Gen. Tech. Rep. SO-93. Southern Forest Experiment Station. Asheville, NC.

Rodin, L.E. and Bazilevich, N.I. 1967. Production and Mineral Cycling in Terrestrial Vegetation. Oliver and Boyd, London. 288 pp.

Rummer, R.B., Stokes, B.J. and Lockaby, B.G. 1995. Sedimentation associated with forest road sufacing in a bottomland hardwood ecosystem. Forest Ecology and Management. In press.

Scott, M.L., Kleiss, B.A., Patrick, W.H. and Segelquist, C.A. 1990. The effect of developmental activities on water quality functions of bottomland hardwood ecosystems: the report of the water quality workgroup. In: J.G. Gosselink, L.C. Lee, and T.A. Muir (eds). Ecological Processes and Cumulative Impacts. Lewis Publishers, Chelsea, MI. pp. 411–454.

Sharitz, R.R. and Mitsch, W.J. 1993. Southern floodplain forests. In: W.H. Martin, S.G. Boyce, and A.C. Echternacht (eds). Biodiversity of the southeastern United States: Lowland Terrestrial Communities. John Wiley and Sons, Inc. New York. 502 pp.

Shelford, V.E. 1954. Some lower Mississippi Valley floodplain biotic communities; their age and elevation. Ecology 35: 126–142.

Stanturf, J.A., Hodges, J.D., Lockaby, B.G. and Schoenholtz, S.H.. 1995. Restoration of dynamic ecosystem: lessons from forested wetlands. Paper presented at the IUFRO XX World Congress, August 1995, Tampere, Finland. Division I, Restoration of Degraded Landscapes.

Shepard, J.P. 1994. Effects of forest management on surface water quality in wetland forests. Wetlands 14(1): 18–26.

Stokes, B.J. and Schilling, A. 1995. Improved harvesting systems for wet sites. Forest Ecology and Management. In press.

Vitt, L.J., Caldwell, J.P., Wilbur, H.M. and Smith, D.C. 1990. Amphibians as harbingers of decay. Bioscience 40: 418.

Walbridge, M.R. and Lockaby, B.G. 1994. Effects of forest management on biogeochemical functions in southern forested wetlands. Wetlands. 14(1): 10–17.

Walker, L.C. 1991. The Southern Forest: A Chronicle. Univ. of Texas Press, Austin. 322 pp.

Wharton, C.H. 1978. The Natural Environments of Georgia. Georgia Dept. of Natural Resources, Atlanta, GA. 227 pp.

Will, G.M., Hodgkiss, P.D. and Madgwick, H.A.I. 1983. Nutrient losses from litterbags containing Pinus radiate litter: influences of thinning, clearfelling, and urea fertilizer. New Zealand Journal of Forestry Science 13(3): 291–304.

Wyman, R.L. 1990. What's happening to the amphibians? Conservation Biology 4(4): 350–352.

Young, P.J., Keeland, B.D. and Sharitz, R.R. 1995. Growth response of baldcypress to an alterred hydrologic regime. American Midland Naturalist. In press.

Zaebst, T.W., Aust, W.M., Schoenholtz, S.H. and Fristoe, C. 1994. Recovery status of a tupelo-cypress wetland seven-years after disturbance: sylvicultural implications. In: B. Edwards (ed). Proc. of Eighth Biennial Southern Sylvicultural Conference. USDA Forest Service. Southern Forest Experiment Station, Asheville, NC. In press.